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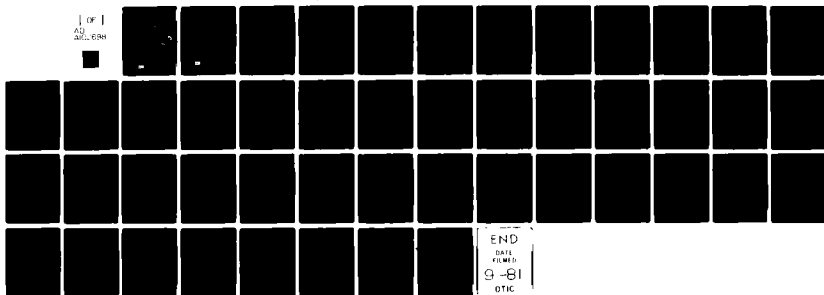
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DEPENDENCE, RISK, AND VULNERABILITY

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I. INTRODUCTION

The purpose of this paper is to articulate a framework for interrelating the concepts of dependence, risk, and vulnerability. To do this we first distinguish dependence (susceptibility to utility losses) from risk (the probability such losses will be inflicted). Then we relate these two concepts through the idea that vulnerability is the expected value of such potential utility losses. Among other things, this approach enables us to highlight those strategies that attempt to reduce vulnerability by lessening dependence and those which aim to reduce vulnerability by lowering the probability that such utility losses will be imposed.

In the second section of this paper, we define dependence and distinguish between two fundamental subtypes -- "positive" and "negative." The third section presents a viable general technique for measuring dependence. Section four considers the relations among dependence, risk, and vulnerability. Section five is concerned with strategies for reducing vulnerability. Concluding remarks follow in section 6.

II. TWO TYPES OF DEPENDENCE: POSITIVE AND NEGATIVE

An actor (A) is dependent on another actor (B) at time t if B can cause a reduction in A's utility at t if B chooses to do so; this is both a necessary and sufficient condition for A to be dependent on B. However, there are two very different subtypes of dependence. For convenience we label them "positive" and "negative."

The distinction between positive and negative dependence hinges on the relation between changes in the extent of the actor's dependence and changes in the dependent actor's utility level. Increases in A's positive dependence on B will (definitionally) result in greater total utility for A, at least other things equal. By contrast, any increases in A's negative dependence on B will not result in such increases in A's utility level, other things equal; such increases will probably (but not necessarily) lead to decreases in A's current level of utility. Inattention to this distinction may be at the core of much ambiguity in the current "dependence" literature. Let us try to elaborate.

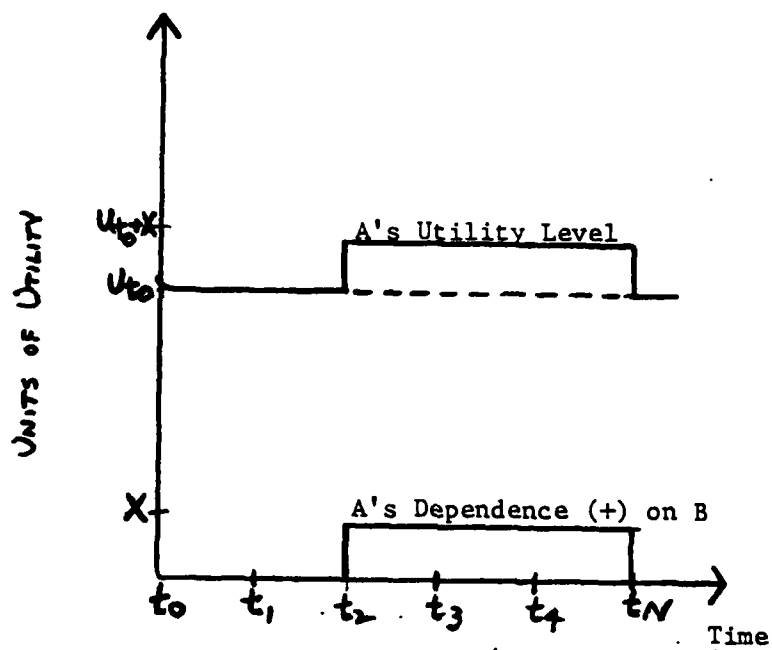
Consider a simple, stylized case in which A is not dependent on any other actor at t_0 , e.g., A is completely isolated from all other actors at that initial time. In fact, for simplicity assume that no other actors exist or at least that none can con-

tact A in any way. Also assume that at t_0 A has a total utility or level of well-being equal to U_{t_0} per year.

Into this rather stark world arrives a second actor, B, at time t_1 . Then at t_2 B begins providing A with a stream of goods -- free of charge -- which A is delighted to have and which increases A's level of utility by X per year. Beginning at t_2 , therefore, A now starts to enjoy a utility (per year) higher than at t_0 or t_1 , i.e., $U_{t_2} = U_{t_0} + X$.

B is thus by t_2 providing A with goods A wants at less cost than A could otherwise have obtained them. By adding to A's utility in this ongoing way, B has made A more dependent on B at t_2 than A had been at t_0 or t_1 -- that is, more positively dependent. Other things equal, moreover, B can at t_3 impose more harm on A than it could at t_0 or t_1 , because B can take away something in the next period that it is now giving to A. At t_0 or t_1 it was not giving anything it could take away. By providing a stream of benefits to A, B is now in more of a position to harm A's (new, higher, t_2) level of utility than it was before it began providing the benefits to A or would be if it withdrew them. Finally, if B did withdraw those benefits (at t_n) A would be less dependent at t_n than at t_2 -- but also back at a lower total utility level (U_{t_0})¹

Figure 1: Effects of Changes in A's Positive Dependence on A's Utility Level



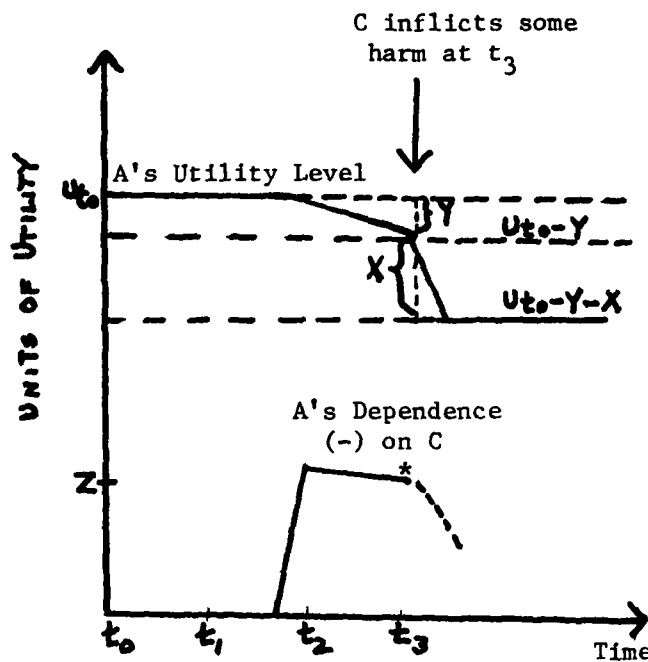
Now, on the other hand, consider a case of increasing negative dependence. This can be viewed as any increase in the ability of one actor (B) to impose harm on the (increasingly) dependent actor (A), but without any commensurate utility gains for the dependent actor. Examples would be increases in B's ability to do greater physical damage to A, or in B's ability to increase the prevailing market price for a good demanded by the other actor (but in the absence of a prior, downward effect on the market price),² etc. To illustrate, we focus on the ability to do physical damage.

As before, imagine (as in figure 2) that at t_0 A is totally out of even potential contact with all other actors. Assume, too, that at t_0 A again has a total utility equal to U_{t_0} per year. Now at t_1 actor C arrives, and is completely unarmed. By t_2 , however, C, while engaged in no ongoing contacts with A, has developed weapons it could use to inflict some damage on A if C so

FIGURE 2 HERE

chooses, which could thereby decrease A's level of welfare. Although A may have developed the capacity (between t_1 and t_2) to physically prevent some of C's new missiles from reaching its territory should C launch them, let us say there is a certain amount of damage (Z), that C can do to A regardless. At t_2 , A is more negatively dependent on C than it had been at t_0 or

Figure 2: Effects of Changes in A's Negative Dependence on A's Utility Level



Y = total amount of resources A spends per period just prior to t_3 to reduce expected damage

X = harm imposed by C at t_3

* (see footnote 3)

t_1 . But note that in this case A's utility level at t_2 has not increased (relative to what it had been at t_0 or t_1) despite this increase in dependence of A on C by t_2 . In fact, A's current (t_2) utility level may well be (but need not be) less than at t_0 or t_1 . It probably will be less because A is likely to be diverting resources (shown in figure 2 as costing Y in A's utility by t_3) from production of consumption goods to its self-defense (when it would rather not have to protect itself). But, on the other hand, A may "enjoy a fight" (not illustrated), or simply be unaware of such increases in C's ability to inflict such damage (and so its utility until t_3 might remain at U_{t_0}). In this kind of general case of increased negative dependence of A on C, if C in fact inflicts X units of harm on A at t_3 , then, as in the case of positive dependence, A's level of utility will clearly decline (by X units) compared to U_{t_0} , other things equal. But recall that in the case of negative dependence, A's t_2 utility was no higher than it had been at t_0 or t_1 . Consequently, A's utility level at t_3 will (generally) have declined below what it had been prior to the dependence.³ In the case of positive dependence, however, any reductions in positive dependence will only (in general)⁴ return the dependent party to its pre-dependence level of utility, at least other things equal.

III. MEASUREMENT STRATEGIES: DEPENDENCE

This fundamental conception of A's dependence on B -- as equivalent to a situation in which A can be hurt (suffer utility loss) by B -- begs for elaboration in degree. In other words, how are we to distinguish variations in actors' dependence on other actors?

Dependence vs. Vulnerability

As noted in the introduction, we view dependence and vulnerability as distinct concepts. Vulnerability is not herein construed as a type of dependence. This contrasts with Keohane and Nye's (1973) formulation of the concept, for example, so it is well to be specific about our differences. Keohane and Nye distinguish between sensitivity and vulnerability "dependence." We strongly agree with Baldwin (1980) that "sensitivity dependence" implies nothing more than the minimal connectedness of behaviors or parts in two or more (nominally) distinct social systems. We believe (with Baldwin), that Keohane and Nye's "vulnerability dependence" (defined as "continued liability to costly effects imposed from outside, even after efforts have been made to alter or escape the situation")⁵ is analytically closest to the meaning of dependence (as we define it) -- a hurt can be imposed if the actor you depend on so chooses. But dependence need not imply more than a minimal probability that the hurt will be imposed. As

we view it, how vulnerable to a given amount of hurt a dependent actor is -- with the amount of hurt (i.e., utility loss) he could receive being the measure of his dependence -- will vary with the chance that the given amount of hurt will be inflicted.⁶

In the recent literature on trade dependence (e.g., Caporaso, 1978; Baldwin, 1980) the notion of measuring A's import dependence on B as the "opportunity cost" involved in A's being forced to shift from B to its next best possibility has gained increasing favor. While we also believe that a dependence formulation in terms of opportunity cost is appropriate, we have yet to see either an articulation of just what would be involved in such a measurement strategy or a comparison of an opportunity cost approach with a so-called "consumer/producer surplus" approach to the losses an importer (A) would sustain if a particular seller did the maximum damage it could to A, to the market, or to both. Such a discussion may help shed some light on the key issues involved. For one thing, A may be dependent on sellers with which it has no direct market exchanges, which suggests that the bilateral formulation of opportunity cost just mentioned is too restrictive. For another, the opportunity cost of being forced to shift to one's next best alternative is a meaningless phrase in terms of the strict definition of opportunity cost in the economic literature. Thirdly, and more importantly, the consumer/producer surplus framework, while eminently sensible (though not perfect) for assessing the utility losses to A due to a given world price

increase for a commodity A is buying, is insufficient to identify the amount by which a particular seller can affect the market price. The remainder of this section will elaborate on these points and, in so doing, describe the applicability of the consumer/ producer surplus approach as part of an overarching (generalized) opportunity cost framework for gauging one actor's import dependence on another party or group of actors. After doing so, we will then proceed to an examination of the major considerations which seem to be involved in assessing one actor's vulnerability to hurt by another. In the last section of the paper we will then briefly examine some of the strategies and policies a dependent actor may want to adopt to reduce its vulnerability.

Dependence as Opportunity Costs

The idea of an opportunity cost can be simply stated. When A does X_1 with a given amount of resources, he does not do X_2 , X_3 , etc., with those resources -- so long as these are mutually exclusive options. If X_2 is his next best alternative to X_1 , the opportunity cost to A of doing X_1 is the total value to A were he to do X_2 instead.⁷

Note that the opportunity cost concept is not defined as either the net loss to A of being forced to do X_2 instead of X_1 , nor as the net benefit to A of doing X_1 rather than X_2 .

Rather, it is the total value of one's next best alternative if one is doing X_1 . However, dependence as we define it is really the amount of loss one would incur in being forced to move to one's next best alternative (X_2), rather than being allowed to continue doing X_1 .

In any case, if this concept is applied to A's dependence on a particular foreign supplier (B), consider first the simple situation in which B is one of an infinite number of suppliers of the commodity (i) A is interested in. Assume further that A is importing most of the commodity i it imports from B, but that this amount represents an infinitesimal amount of the total amount of i for sale on the international market. Now if B suddenly stopped producing i, or if B continued to export i but refused to sell i to A, A's opportunity cost would equal the benefit from the initial situation; A would incur no net loss because B was completely powerless to influence the market price for good i. There might be minor transactions costs for A due to the move to some new supplier, but these would be so small as to be irrelevant.

At the opposite extreme, if B were one of very few suppliers of i in the world, if A imported i, and if B suddenly significantly raised its asking price for i, what would A's net loss be if forced to shift to its next best alternative? The costs to A in this case will hinge critically on several factors, including the price elasticity of supply of i, A's price elasticity of demand

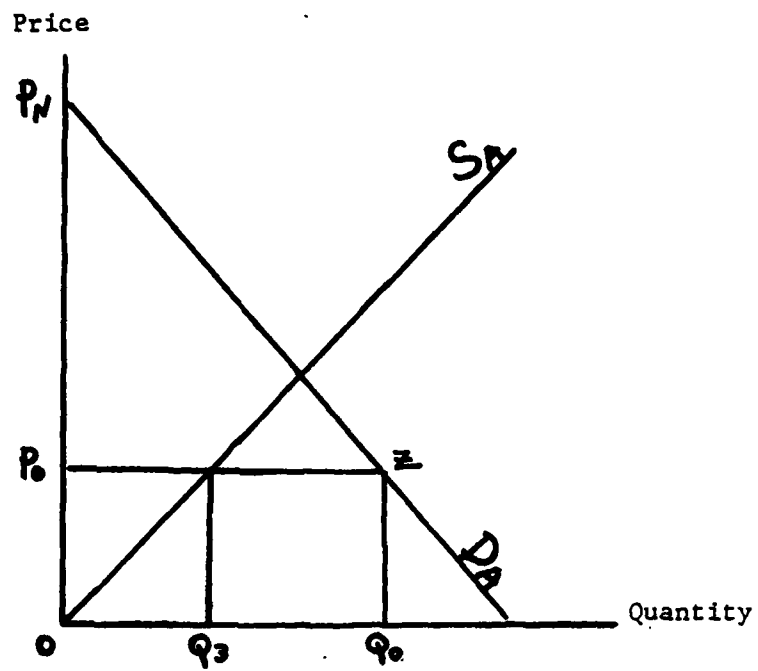
for i , and the quantity of i A had previously been importing. All these factors -- plus the reduction in the amount of i B will supply to the market -- will jointly define the amount of the loss A would sustain as a consequence of B's action (note that this specific action by B may not be the most damaging action of which it is capable; it might have stopped exporting i altogether). We define A's actual dependence on B as the maximum amount of damage B can impose on A if it so chooses. The specific way in which these factors combine, and the amount of loss A will sustain in this case, are depicted graphically in figure 3b.

First, though, it may be useful to clarify some fundamental referents in this approach. Figure 3a illustrates the situation confronting A prior to such a price increase.

FIGURE 3a HERE

In figure 3a, party A is consuming quantity Q_0 of commodity i and is paying price P_0 per unit of the i it consumes. S_a represents A's domestic supply curve for i and D_a represents A's domestic demand curve for i . P_0 is the prevailing global market price for i . Domestic producers are supplying quantity Q_3 of good i to A, and foreign suppliers are supplying the remainder, i.e., $Q_0 - Q_3$. As can easily be seen, domestic producers are receiving revenues equal to $P_0 \cdot Q_3$ from A's users of i , while foreign suppliers are receiving revenues equal to $P_0(Q_0 - Q_3)$

Figure 3a: Baseline situation A confronts
prior to price increase



from A's users of i . A's users of i are thus paying $P_0 \cdot Q_0$ to obtain Q_0 units of good i (per period, e.g., per year) in this situation.

But now note that in any situation such as this, A's users of i are receiving greater utility from these purchases than they are being required to pay for. This extra utility can be labelled a "consumer surplus." (In fact, it can be thought of as "gains from trade".)⁸ In this situation, A's users are receiving a consumer surplus equal to the large triangular area in figure 3a (bounded by the vertical line P_0 , the distance on the vertical axis $P_n - P_0$, and the hypotenuse running from P_n to Z on A's domestic demand curve).

The key to this idea of a consumer surplus is that, at any price short of P_n , at least some of A's consumers of i are able to buy commodity i for less than they would be willing to pay for it if they had to. In fact, the prices they would be willing to pay for various marginal amounts of i are represented by the domestic demand curve (D_a).

Now, given this, if B was able to suddenly increase the prevailing market price from P_0 to P_1 , a basic measure of A's total loss of utility due to such an increase would be the sum of the areas 1, 2, and 3 in figure 3b. Although several refinements can be offered, they are all elaborations on this basic measure-

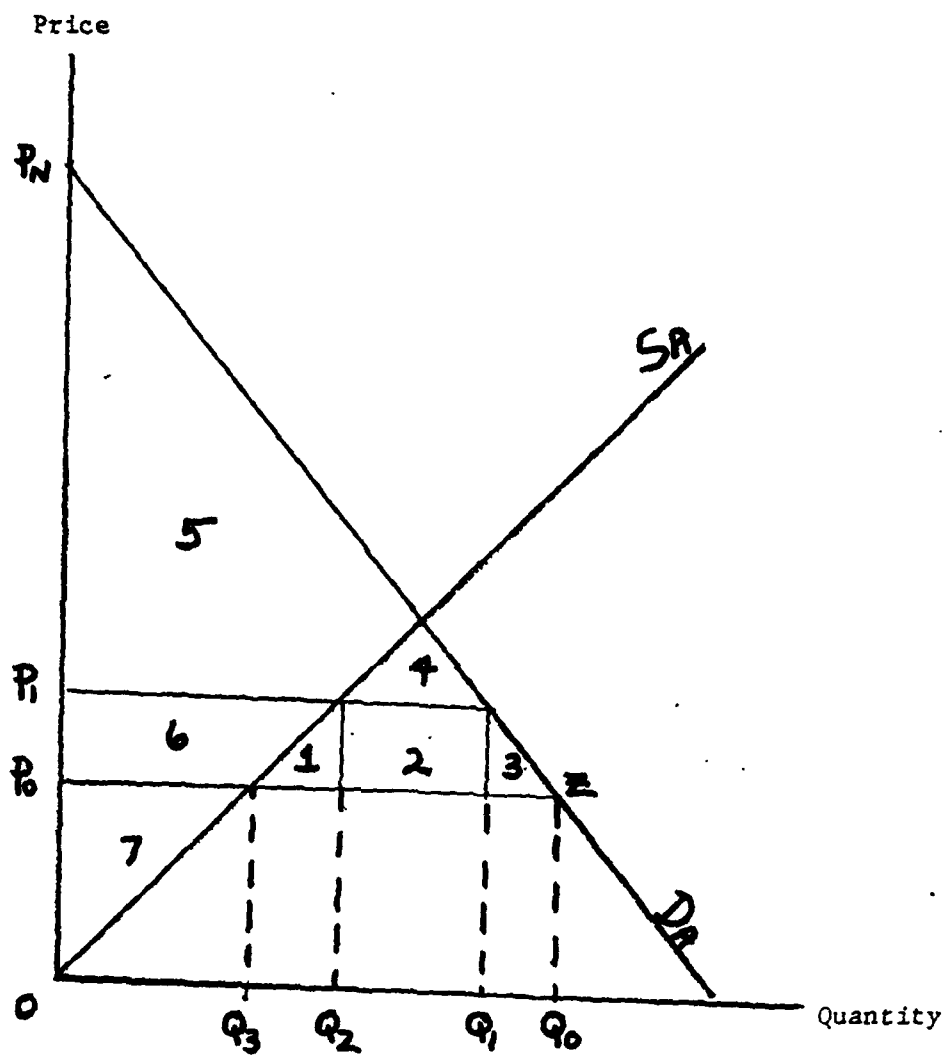
ment procedure. A description of the logic and assumptions underlying this measure strategy may be in order.

FIGURE 3b HERE

With an increase in the prevailing market price for i (from P_0 to P_1), A's users will pay more per unit and consume less, A's domestic producers of i will be able to sell more i (to A's users) at higher prices, and A's domestic producers will waste resources on the production of this extra i (compared to the greater efficiency enabled when the global market price was P_0). In sum, A's users of i will lose consumer surplus. Some will be lost to foreign producers (area 2), some will be lost to domestic producers (area 6), some will be a so-called "deadweight loss" (area 3) -- gained by no one -- and some will be lost to inefficient use to produce i within A (area 1).

Now considered as a single entity, A's total utility loss (as opposed to simply A's users' losses of consumer surplus) from this price increase will be equal to its consumer surplus losses (areas 1, 2, 3, and 6) offset by the "producer surplus" gained by domestic producers (area 6) in the process -- i.e., the revenues domestic producers themselves now receive from A's users over and above their costs of production of i . (Area 6 can be seen to be over and above the costs of production because it is outside the area

Figure 3b: Fundamental components of
consumer/producer surplus analysis



bounded by the domestic producers' supply curve (S_a), which is in effect a line depicting domestic producers' marginal cost of production of i .)

Note that even at price P_1 , however, A's users of i still continue to receive a consumer surplus in their purchases of i . At P_1 this remaining consumer surplus will equal areas 4 plus 5 in figure 3b.

Now to actually estimate the dollar value of the utility loss to A per period that would be involved in any such shift in price as depicted in figure 3b, we can use the following basic equation -- which represents the area under the domestic supply and demand curves over the price range P_0 to P_1 :

$$\begin{array}{l} \text{Utility loss} \\ \text{to A per} \\ \text{period} \end{array} = \int_{P_0}^{P_1} [S_a - D_a] dP$$

Refinements and Limitations

This framework offers the most basic measurement strategy for assessing A's (per period) utility losses due to a price increase of the sort just described. As mentioned, a number of refinements are possible. Two such possibilities are now presented.

First, domestic supply and demand elasticities are typically larger the longer the period considered. For this reason alone, in calculating the total utility losses due to a given price increase, costs per period will be highest in the short-term, less in the mid-term, and least in the long-run. Secondly, consider that individuals are known to attach higher value to losses (and benefits) in the short-term than in the long-term, even if the anticipated inflation rate is zero. Therefore, in calculating the total utility losses A expects to sustain over a given period of time, a procedure known as discounting⁹ has been developed -- to reflect A's presumed relative concern about immediate losses versus losses in the longer run.

In any case, this kind of basic framework seems essential in any efforts to gain a systematic handle on the "hurt" that a specific type of event will impose on a particular consuming nation A. This does not mean it can be easily applied, with no honest differences of opinion in the assessment of damage that a given society would sustain if confronted by a partial supply disruption. As we see it, a number of uncertainties and difficulties are relevant here.¹⁰ First, relevant parameters, particularly price elasticities of supply and demand, are open to significant and legitimate debate for most goods. This problem is the more difficult since the sorts of price increases implied by some kinds of supply disruption scenarios of interest to us are outside the range of prior experience.

Second, there are questions about the distribution of the losses sustained within A. Third, this utility loss measurement procedure (as outlined) does not capture all the further losses in secondary markets which use good i as inputs to production. Fourth, this framework does not fully capture A's losses due to reduced demand for A's goods abroad due to a "depressed" international economy. Fifth, some arguable assumptions about the constant marginal utility of the dollar are made.

Sixth, potential political and security costs of possible price increases have never to our knowledge been incorporated within this measurement framework. Perhaps they can be, although this is not well understood at present. Potential political costs to A may include loss of support from other actors and loss of influence. Potential military/ security costs might include increased difficulty of attaining specific security objectives.¹¹

Seventh, A is assumed not to derive positive utility from any such price increase nor from the prospect of an international challenge. Yet there may be members of A who are thoroughly delighted at the chance to "wreak revenge." Moreover, a significant disruption may be viewed by some members of A as a "necessary" lesson to A in the importance of self reliance, in the reality of external threats, in the importance of a better strategy, etc. These are legitimate problems. But this framework can still

serve as the basic measurement strategy -- with refinements added as they are more clearly understood. Some problems will be intractable, but all we can do is make suitable assumptions and avoid decisions which blindly ignore their intractability.

While a consumer/producer surplus framework can in principle allow us to gauge the utility losses A would sustain due to a given price increase for a unit of good i , to assess the harm a particular actor B could impose on A demands additional information.

For example, in the case of A's import dependence on B, we need to at least determine how much of an adverse effect the particular supplier (B) can have upon the prevailing world price for the commodity in question. (We assume here for simplicity that B is not selectively subsidizing A's purchases of i below the prevailing global price.) Recall that, in figure 3b, it was the shift in the world price for commodity " i " (from P_0 to P_1), which occasioned A's utility losses equal to the sum of areas 1, 2, and 3. Consequently, to assess A's import dependence on B we need to determine how large a price increase B can impose on A insofar as A's imports of i are concerned.

To assess this it is convenient to refer to a simplified version of the international market for commodity i . This is shown in figure 4. The global demand curve for " i " is given as

D_G . The global supply curve is given as S_{G_0} at time t_0 . At t_0 , quantity Q_0 is being supplied (and purchased) at a prevailing global price P_0 .

FIGURES 4 AND 5 HERE

Assume that at time t_1 supplier B withdraws all its exports of i from the market. This quantity is represented by $Q_0 - Q_1$, where Q_1 represents the total supply of " i " left for purchase on the market at t_1 after B withdraws. This action will lead to a shift in the supply curve (from S_{G_0} to S_{G_1}) and an increase in the the prevailing world price from P_0 to P_1 . Our object here is to determine the value of P_1 .

Now assuming we know the slope of D_G and the potential change in quantity supplied ($Q_0 - Q_1$), we can estimate the change in the prevailing global market price $P_1 - P_0$ (and the expected new market price P_1), as follows.

If the slope of D_G can be represented as:

Figure 4: Initial effect on world price of drop in B's supply

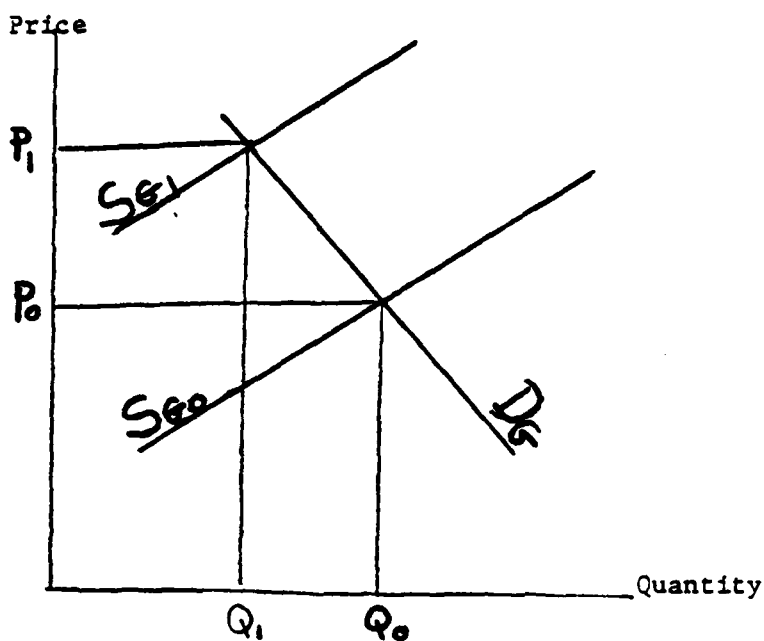
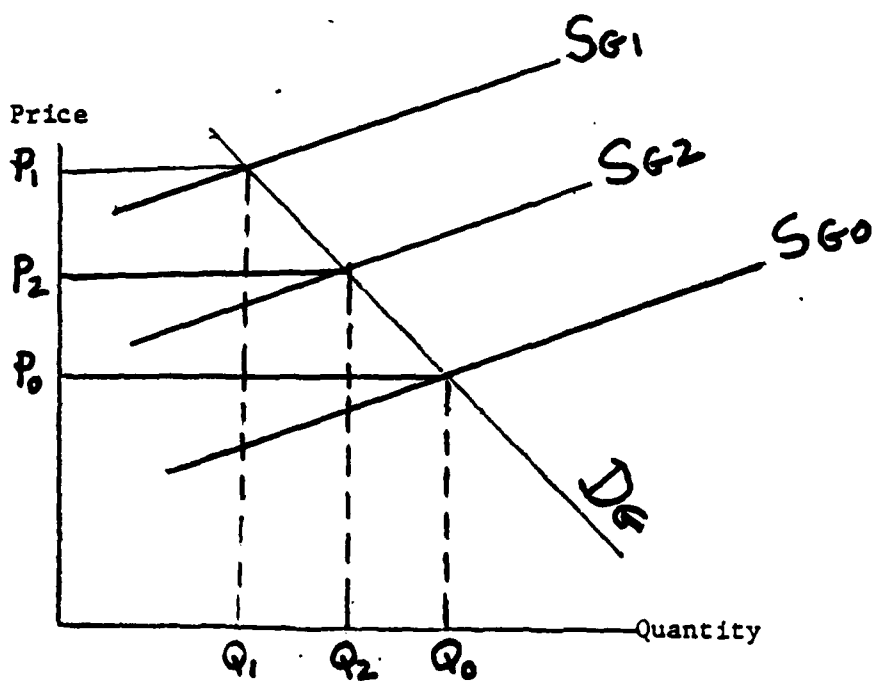


Figure 5: Secondary effect on world price and supply of drop in B's supply



$$\alpha = \frac{\Delta Q}{\Delta P} = \frac{Q_1 - Q_0}{P_1 - P_0};$$

then,

$$P_1 - P_0 = \frac{Q_1 - Q_0}{\alpha}, \text{ and}$$

$$P_1 = P_0 + \frac{Q_1 - Q_0}{\alpha} = P_0 + \frac{Q_0 - Q_1}{-\alpha}.$$

It must be emphasized that figure 4 offers only the most simplified, basic case. A key omission, for example, is the recognition that non-B's will react to this initial shift in the supply curve (in figure 4) by increasing their own production, release of inventories, etc., to try to capture additional profits. This will tend to shift the supply curve (due to the price increase) back to the right -- as shown in figure 5. Still, the supply curve is not likely to shift all the way back to its original position (S_{G_0}), since the costs of such additional production by others are likely to be higher than they were for B.

This approach -- outlined above -- is an effort to give more content to an opportunity cost version of the concept of at least one kind of dependence than we have thus far seen in the general literature on the topic. It is by no means complete. Yet it seems to us to be a step in the right direction in outlining a general schema for measuring A's dependence on particular Bs.

Within this framework it should be apparent that A might be more import dependent for commodity i on a producer of i it has no

direct dealings with than it is on its own particular supplier(s) of i . This will not necessarily be so, of course, but it could be the case. It seems intuitively quite plausible to view the matter in these terms, at least for many purposes. After all, if A is importing its i from a comparatively tiny producer (B_1) in an international market, and none from a very large producer (B_2), B_1 may have little or no capacity to influence the prevailing global market price for i while B_2 has a great deal. The measurement strategy outlined here will gauge A 's import dependence on B_2 as greater than A 's import dependence on B_1 . One way to summarize this approach is to note that we see "indirect" import dependence as potentially at least as important as "direct" dependence. Another way to view this issue is to say that this measurement approach assumes that transaction costs are relatively small and that the markets involved are truly international institutions. We see little clear evidence to suggest otherwise. In any case, the matter is at least in principle open to empirical investigation.¹²

IV. RISK AND VULNERABILITY

That A can be harmed by B (is dependent on B) does not mean A will be harmed. Capacity does not imply intent. Moreover, signals of intent to impose harm may be a bargaining bluff. Yet calling a bargaining posture a bluff too loudly may lead to imposition of some harm.¹³

If A depends on B for X units of utility per period, there is some chance (P) that B will inflict that harm X on A within the next period. A's "expected losses" or "expected value of loss" (EVL_{t_1}) in period t_1 can be conceived most simply as

$$EVL_{t_1} = X \cdot P = \text{A's vulnerability to damage by B in period } t_1$$

Note that the true chance (P_A) that B will inflict the harm it can inflict on A during a particular time period (t_1) may be quite different in practice -- and certainly is in principle -- from A's subjective estimate (P_S) of that chance. Similarly, the amount of damage A expects B to be able to inflict on A (X_B) may be quite different from the amount of damage B is in fact capable of inflicting (X_A). To the extent we can gauge both the true chance and the true amount of damage B can do, we can arrive at a measure of A's true vulnerability to damage by B. The key point is that there is no necessary correspondence between A's perceived and actual vulnerability to such damage. A's subjective estimate may be higher, lower, or the same as the actual value. We need to focus closely in future work on the implications of such potential discrepancies.

A's actual vulnerability to damage by B (EVL_A) could logically increase in any of five basic ways. P_A could increase while X_A remains the same. X_A could increase while P_A

remains the same. P_A and X_A could both increase. P_A could decrease but X_A could increase more than enough to "compensate." Or X_A could decrease but P_A could increase more than enough to compensate.

Estimating P_A is obviously complex. It may seem reasonable to assume that

$P_A = f(V_B)$, where V_B equals B's expected net benefit (value) from imposing the harm on A (and where V_B itself equals the expected gross benefits to B from imposing the harm minus the expected gross costs to B from imposing the harm). But it is also quite plausible that the greater the net benefit B expects to be able to obtain from imposing the harm, the more likely A will try to either reduce the net benefit or reduce it relative to the benefit B receives from a negotiated solution not so damaging to A.

This in turn suggests that

$$P_A = f(V_B - VA_B)$$

may be more plausible, where VA_B is the expected net benefit from a compromise offer by A that improves for B on B's own expected utility from simply avoiding the harmful act against A.

This complexity alone, that $P_A = f(V_B - VA_B)$, makes the assess-

ment of EVL_A a highly challenging problem for further theoretical, measurement, and empirical work. But the core idea is that $EVL_A = P_A \cdot X_A$.

P_A will generally be very low if V_B is low, and V_B may be low for a variety of reasons. A may retaliate. B may automatically lose benefits from A, e.g., revenues. Others may retaliate. B may automatically lose benefits from non-A's.

The counter-hypothesis that increased profits will necessarily accrue to B through such price increases or import-interruptions ignores at least two important points. First, it is generally reasonable to assume that producers are already trying to maximize profits at any given point in time. In general, therefore, we have little reason to assume they will benefit economically from greatly changing their level of production -- except to keep prices from falling.¹⁴ This does not guarantee against sharp changes, but it is a strong disincentive. Secondly, producer attempts to increase short-term profits drastically will increase the chances that consumers (not just A) will strongly accelerate the pace of substitution efforts, which may well reduce the long-term profit maximization chances for the particular suppliers.

An additional factor which may reduce P_A consists in the generalized political costs to B which may result from B's efforts

to impose harm on A. These may be greater than are first apparent. After all, embargoes and price increases are very difficult to selectively impose (on a given consumer), as history has repeatedly shown. It is therefore quite plausible that B's efforts to hurt a given party (A) will have a far greater combined adverse effect upon other consumers than upon A itself. Such negative economic consequences may well redound to the net political disadvantage of party B.

Now if A depends on B, then B can if it chooses impose that hurt on A. A will be less vulnerable to damage that B can impose the less willing B is to impose that damage, at least other things equal. But the damage B can impose on A could be imposed on A even if B is unwilling to impose it. This could obviously occur if B loses control over its own activities. Internal strife (within B), accidents of weather, flooding, etc., conflict between B and third parties, or possible third party efforts to disrupt B's relations with the rest of the world are all ways in which this control might be at least partially lost.

The practical implication of this consideration is that, while A's vulnerability to the specific damage B can inflict will be smaller the less willing B is to inflict it, B's unwillingness to inflict damage is not sufficient to render A invulnerable to such damage. In short, P_A will be a function not just of V_B (and potentially of $V_B - V_{AB}$): it will also be a function of

both the likelihood that B will lose control over its own activities as well as the likelihood that, if B does lose this control, the damage will then be imposed.

V. REDUCING VULNERABILITY

Actors seeking to reduce their vulnerability to damage appear to have two broad avenues of approach. They can try to deter the damage, i.e., reduce the chances someone will try to impose it. Or they can attempt to reduce the amount by which their utility level could be damaged by other actors even if those actors should try to inflict the damage. These are not mutually exclusive. In any case, efforts to achieve either of these results have costs as well as the potential for success. There are not likely to be any guaranteed ways to achieve either result. Although some policy prescriptions are tempting to view as sure moves in the right direction, we need to understand some potential pitfalls before embracing specific proposed techniques as even partial "solutions."

A general rule of thumb in dealing with vulnerability presumably should be that you want to try to reduce both the chances the damage will be imposed and the amount of damage if an actor tries to impose it, but only so long as the costs of your efforts don't outweigh the benefits you are likely to gain.¹⁵ In applying

this rule, consider, for example, the implications vis-a-vis positive and negative dependence situations.

Assume A is, in the case of positive dependence, receiving a stream of benefits (X) from B at t_2 which he could not obtain for free elsewhere (as in figure 1). One way for A to reduce his vulnerability at t_3 is to refuse to accept any benefits from B. This will lower his dependence on B at t_3 compared to t_2 : after t_3 B can impose less future harm on A than B was able to impose at t_2 . But this sort of approach has the obvious disadvantage of also reducing A's utility level in the process, and represents a kind of pyrrhic victory. Despite its disadvantages, this type of strategy seems to us to bear a strong resemblance to most efforts to reduce imports (e.g., Project Independence during the Nixon-Ford Administrations) through policies such as tariffs and import quotas.

In the case of positive dependence, however, if it is possible for A to reduce its positive dependence without reducing its current (t_2) utility position, it seems entirely rational to try to do so. An obvious line of approach here is to attempt to build a network of alternative sources and substitutes able to provide some portion of the benefits A now receives from B -- in the event B should withdraw those benefits.

But note that the likely net benefits to A of efforts to build that kind of alternate benefit network will hinge on two things: 1) the actual chance B will try to withdraw the benefits it provides; 2) the additional benefit (that is, over and above the value to A of alternative sources that would be available -- should B withdraw its benefits -- even if A had not spent resources to build such a network) that this alternate network would provide to A (assuming B did withdraw) compared to A's cost of building it.

As a concrete illustration of some potential problems involved here, consider the issue of U.S. government stockpiles of crude oil -- the Strategic Petroleum Reserve (SPR). The major rationale for building up the SPR appears to be that it would provide the U.S. civilian sector with additional, badly needed oil in a severe oil crisis. Although it is sometimes assumed vital for U.S. military purposes, this has not been demonstrated. Note that SPR oil is crude oil, not militarily usable products. The military has its own, totally separate, stockpiles of usable fuel. Obviously, though, military inventories could run out. But the U.S. has (and will have for many decades) far more than adequate domestic crude oil production¹⁶ (and refinery) capacity¹⁷ to supply the U.S. military in wartime -- unless the U.S. is massively attacked. (If attacked, SPR (crude) oil would not be directly usable anyway.)

But how much help would extra SPR oil be to the civilian sector? On the surface, additional SPR crude oil would seem to help moderate extreme domestic prices for oil in a severe oil import disruption. Note, though, that this effect may be much smaller than often thought. The key problem is as follows.

Whatever moderating effect on prices SPR releases might temporarily have on U.S. domestic prices, they will also reduce the incentives of international oil companies to sell to U.S. consumers whatever foreign oil they might otherwise be willing to bring into the U.S.; SPR releases would thus increase their incentives to sell that foreign oil overseas (where the prevailing price was higher). To try to force the oil companies to do otherwise may be an appealing prospect. But succeeding in this effort would be a quite different proposition.

To our knowledge, no effective mechanism has yet been devised to cope with this very real problem. Thus, despite the surface appeal and emotionally attractive aspects of a large Strategic Petroleum Reserve, it is not immediately apparent that it will have anything like the advantages -- even for the U.S. civilian sector -- that are often claimed for it.

SPR releases may help moderate world oil prices in such a crisis, but since they are likely to be a relatively small proportion of the global supply available -- even in a severe oil

disruption -- the net benefit to the U.S. civilian sector may be quite small. We do not come to this conclusion happily, but the example does suggest some of the very real difficulties in devising effective ways to reduce the costs of trade disruptions -- should they occur.

In any case, it is rational for A to consider that if it can't substantially reduce its positive dependence without thereby reducing its utility, it does not gain by refusing to accept the current benefits which its dependence on B provides.

In such a case, A can still attempt to reduce the chances that those benefits which B uniquely provides will be withdrawn. Again, however, A must bear in mind that chance-reduction strategies have costs as well, and that individual strategies are not necessarily suited to the particular source of risk.

As an example of the first point, note that political concessions to suppliers so as to forestall price increases or embargoes are neither clearly necessary nor sufficient to the objective. Nor is it clear they have made or will make a difference in pricing policies for states that have offered concessions.¹⁸ A key reason is that selective embargoes or preferential pricing schemes in global markets, while easy to try, are very difficult to enforce: the pressures to participate in "secondary markets" are usually extremely strong.

As an example of the problems in tailoring a deterrent strategy to the particular source of risk, it is well to emphasize that while credible military instruments may help deter third party efforts from harming A by severing important trade links (whether these are direct or indirect trade links), these instruments may prove powerless to deter the damage should it stem, for example, from internal strife in B.

From a policy standpoint, dependence and risk reduction strategies need to be considered from the twin perspectives of expected net benefit and suitability of the instruments. We do not mean to imply here that no such strategies can work. But it is important to attend to key limitations of specific policies so as to help decision-makers devise suitable means to achieve appropriate national objectives.

In situations of positive dependence, A's efforts to reduce the amount of damage B could impose should be devised to avoid reducing the benefits which at least B is now providing. In cases of negative dependence, A will not (normally) be obtaining any current benefits from that dependence per se (as illustrated in figure 2). Here too, though, A has rational incentives to reduce both the damage which could be done and the chances of that damage being imposed -- so long as A's costs of such efforts are less than the gains achieved thereby.

Deterrence theory and policies seem relevant here. What may not be as obvious is the pervasive formal similarity between strategic deterrence issues and strategies for reducing vulnerability to damage in the realm of economic dependence relations. This is not the place to elaborate on these similarities or on possibilities for cross-fertilization in the two subject areas. Still, in light of these issues, it is intriguing that the cornerstone of strategic deterrence theory has long been the notion of automatic, immediate and catastrophic consequences for the aggressor should it attempt to inflict harm.¹⁹ Is it possible that a vigorous emphasis on the very likely widespread adverse effects on many nations of any efforts by B to inflict highly targeted economic harm on A could itself be a potent deterrent to B in many cases?

This sort of strategy will by no means always be sufficient. Nothing will deter an adversary whose greatest joy is inflicting harm on you and who pays no attention to likely damage to himself as a result of inflicting such harm. All one can do in such a situation is physically prevent the adversary from doing the harm he otherwise would.

Fortunately, there are few such actors in the international arena today, despite rhetoric and bargaining postures to the contrary.

VI. CONCLUSIONS

The foundation for an understanding of the extent of a given actor's dependence on another seems to reside most basically in an appreciation of the amount of harm (i.e., utility losses) the second actor can impose on the first. In this paper we have attempted to lay out what appear to be the key elements in that sort of conceptual measurement approach to the problem. The approach is by no means fully articulated here. But hopefully a useful beginning has been made.

Given this, we then set out a procedure for gauging -- at least in principle -- the extent of harm which a particular foreign producer of a good is likely to be able to inflict on a particular importer of that good: in loose terminology, our strategy can be labelled an opportunity cost framework, although we have generalized our formulation beyond the popular notion that A must be directly interacting with B to be import dependent on B.

But high dependence does not logically entail high current vulnerability to that harm. We thus set out a framework in which we conceive of vulnerability as a function of both dependence and the risk that the hurt will be imposed.

In the last section we discussed two general approaches to vulnerability reduction. In doing so we considered some potential

difficulties in using political concessions and government contingency stockpiles as instruments for vulnerability reduction.

Finally, we alluded to an interesting potential parallel between the cornerstone of modern strategic deterrence theory (automaticity of adverse feedback), and the likely widespread, systematic effects of attempts by one actor (B) to impose highly focused harm on a particular, economically dependent actor (A).

NOTES

1. Assuming no simultaneous change in availability of alternative benefits.
2. An example would be an increase in B's effective control over a larger share of the supply market.
3. A's negative dependence will presumably decline here also, but this will in practice hinge on the outcome of the conflict: B might wind up even stronger relative to A (if A's defenses were damaged more).
4. See Note 1.
5. See, for example, Joseph Nye, Jr., "Independence and Interdependence," Foreign Policy, No. 22, Spring 1976, p. 133. See also Thomason, 1979.
6. This is essentially an "expected value" approach to the issue. For a general discussion see Hubert M. Blalock, Jr., Social Statistics, Revised 2nd Edition, McGraw Hill, New York, 1979, pp. 137-39.
7. See Paul Samuelson, Economics, McGraw Hill, New York, 1973, pp. 472-3.
8. For a basic discussion, see Samuelson (1973:436-8); for an excellent but highly technical treatment, see Charles River Associates A Framework for Analyzing Commodity Supply Restrictions (1976).
9. See McDougall, D. and Dernburg, T. (1963).

10. A number of these issues are also discussed in Charles River Associates (1976).
11. See Thomason (1980) for a typology of such costs.
12. One possibility is to assess links between A's politically cooperative attempts towards (1) B's it directly trades with, versus (2) B's that are major producers in the market regardless of whether A trades with them, applying suitable controls.
13. See Snyder (1972) for an excellent discussion of the dynamics of such situations.
14. "A profit-maximizer may not be an altruist; but that does not mean he is a fool." See Samuelson (1973: 490).
15. For a brilliant discussion of cost-benefit analysis, see Fischhoff (1977).
16. See Ray Dafter (1979/80). For aggregate data on U.S. military fuel needs see Thomason (1981), The Defense Energy Management Plan (1980), and HASC (198.).
17. See the American Petroleum Institute (1980).
18. We know of no evidence to suggest, for example, that those Western states adopting more pro-OPEC policies on Israel obtain lastingly better market prices for oil imports than those which do not.
19. See, for example, Schelling (1963).

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